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ABSTRACT

This paper describes the design principles for the development of an interactive media project in physics entitled "Beyond Einstein," which is based on the public television series, "The Creation of the Universe." Following a discussion of cognitive science concepts applicable to the development of interactive television, the development of a demonstration tape is detailed, noting that the information to be placed in the database includes short pieces of video, audio, and computer data as well as text. The possibility of using CD-I (Compact Disc-Interactive) as the medium for the project is considered. It is suggested that "Beyond Einstein" represents a first step in the development of information made transparent and attractive to the user, and that it is now necessary to explore in depth the question of whether the possibilities demonstrated in this project are worth further investment. (EW)

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"Beyond Einstein"

A Case Study in Interactive Television

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The Idea of a Learning Laboratory

The best educational television programs are hopelessly overengineered. In a sense, they can never earn an adequate cognitive return on the assets they employ. An example of this is the recent PBS show, "Creation of the Universe," written by Tim Ferris and produced and directed by Geoffrey Haines-Stiles. This program made extensive use of computer graphics costing $4,000 per second to produce. The graphics embodied, in the most intelligent and conscientious way, a virtual textbook on modern particle physics: every detail, down to the smallest and almost imperceptible, signified something real about the particles, the quantum forces, and the structure and behavior of the atom or of the virtual particles that well up out of the vacuum and disappear before the laws of conservation of energy can catch up with them.

While the script valiantly struggles to get the points across, the graphics march across the screen even faster, and are gone.

I would bet that not a hundredth of what is built into this extraordinary material is really perceptible, much less learnable, within the medium, though it serves to tantalize and provoke the viewer. It simply cries out for viewer control of the pace, and for interactivity. And those wonderful computer graphics are there, equally available for use in another medium.

WNET Channel 13 in New York, the premier producer of prime-time programming for PBS, has been aware of this lost opportunity, not just with "The Creation of the Universe" but with a large percentage of its broadcasting. Because of this some years ago the station began thinking about setting up a "learning labratory" where we could conduct research and development on how to design and produce interactive media products related to broadcast series.

Before we could justify such an undertaking, we had to be sure we had thought about our educational and business goals as carefully as we could. We knew that, after we had done our homework, we would have to produce a demonstration of what we had in mind This paper is about what we learned and how it shaped our demonstration of interactive media, "Beyond Einstein," based on "The Creation of the Universe."

The central questions were these:

- In what sense did we want our products to be educational? How was that different from the sense in which our television productions are educational?
- What made us think interactivity was educational?
- Even if we understood what we meant by education and interactivity, how would we translate these ideas into products?
- Why would people want products like these? Why would they be better than other software?
- Even if it made educational sense to develop interactive programs from or in parallel with television series, would it make production and economic sense?

Where Did We Stand on Education and Learning?

One of the first decisions we made concerned audience. We thought about what WNET is expert at—producing information-packed entertainment for a prime-time audience of adults—and what we knew less about—teaching children either formally or informally—and concluded that we should start with the audience we knew best.

Even though WNET has been the presenting station for "Sesame Street" and other history-making children's programming, the real producer of "Sesame Street" was the Children's Television Workshop, which has shown plenty of interest in extending its ideas into interactive formats. Similarly, Bank Street College of Education, Harvard's Educational Technology Center, and several other highly qualified groups were working on educational computing for children.

However, we knew of no group engaged in the development of principled learning materials for adults from about the age of high school juniors on up. Since these are the people for whom we produce most of our television programming, they seemed the right people for whom to develop interactive programs.

There is a startling implication to the idea of producing "principled learning materials for adults" within the context of a PBS producing station. It is that education for us means *self-education*—learning, not teaching. And if learning materials are to be principled, they have to be based on a model of learning, not one of tutoring or teaching. As it turns out, this means they have to be based on what is now being called cognitive science, rather than on more traditional educational psychology.

It also turns out that interactivity demands much more explicitness about why we design programs one way and not another than producing television does. Television production demands great creativity and subject-matter knowledge, but every interactive program also entails a theory of education. The final structure and feel of the program depend on the choice of theory.

The learning theories being codified in modern cognitive science make interactivity seem almost indispensable to effective learning products. However, the kind of interactivity they suggest is often different from what designers of educational programs have accustomed us to, as I'll try to show in due course. Hence, the choice of cognitive science rather than competing educational or behavioral theories leads to innovation. "Beyond Einstein" took us beyond convention and into unexplored zones.

A Digression on Cognitive Science

It is a cliché for which there is plenty of evidence that television, movies, and many other media require very little effort or engagement from their consumers. We all understand intuitively that this means that these media don't provide much intellectual growth—"no pain, no gain."

Our intuition has, of course, a solid underpinning in modern cognitive psychology. This is not the place to go into a detailed examination of all cognitive science has to say on the subject, but some of the arguments for interactivity are most powerfully stated in cognitive terms. Therefore, at the risk of insulting the psychologically sophisticated, I will recap a few of the high points that helped us to shape "Beyond Einstein," and that we think are generalizable to the design and production of any interactive media.

Cognitive psychology is about how we acquire knowledge and how we remember and use it. It is concerned with what is called "knowledge representation," and how this differs among novices and experts in a given field. Knowledge representation is, in brief, our way of mentally "looking at" what we know. Together with knowledge acquisition, it raises a number of issues that are relevant to the informational value of interactivity.

Cognitive psychology has mainly focused on two big topics. The first is how we organize and interrelate information in our minds, and how what we already know helps us learn new information that in turn modifies and restructures our previous knowledge. This topic is basically about knowledge—cognition—itself.

The second topic is not as obvious, but it is critical to self-education. It is called "metacognition," and it has to do with the conscious processes by which we come to understand, remember, and use what we learn. Metacognition deals with a person's awareness of how he or she learns or knows, as well as with the strategies that make learning and remembering more efficient and secure. Obviously, a learner who can assess his or her own understanding effectively and take just the right steps to fill the gaps and remember information will learn more than someone with less self-awareness and fewer "metacognitive" skills.

Knowledge is not facts. Cognitive science suggests that our minds make huge collections of interconnections and categorizations among the facts we learn. We cannot be said to "know" anything until the mind breaks it down and labels it, on the one hand, and cross-relates it to the maximum number of other things we know, on the other. In fact, the difference between an expert on a subject and the rest of us is in part that the expert breaks down new information into more relevant chunks than we do and has more knowledge to connect it to.

In cognitive jargon, the breaking-down process is "schematization," something we might get better at with conscious practice. A somewhat trivial example of a "schema" might be our idea of "car." How could we break that down? Here are some of the ways we all use:

- Make
- Model
- Year
- Engine (4, 6, or 9 cylinders, horsepower, displacement)
- Number of doors (2 or 4)
- Number or seats
- Full size, intermediate, compact, or subcompact
- Power or manual steering

The list can go on for a long time, because we are all experts on cars in this sense. We know the right questions to ask, and we can judge when the answers make sense. Not many of us have as good a schema for particle physics! Still, if we were skillful learners, we would know that we should be working toward one, and that it would be a set of labels to help us direct and monitor our learning.

The other point, about the advantage of connecting new information in webs or maps of relations with every other relevant piece of knowledge in our minds, is even more critical to learning.

More is more. The more we know, the more we understand about new information. The more connections we make among the data in our minds, and the more patterns we form from them, the more secure the information becomes and the easier it is for us to remember in a variety of contexts. The more we know, the better we understand what questions to ask ourselves in seeking or absorbing new information, thus ensuring that we "represent" it to ourselves more fully and expertly.

However, just knowing information is not enough when we are approaching a complex and unfamiliar subject; we also need to know where to begin to make attachments with what we already know. A successful learning program will therefore suggest ways to hook the new knowledge to existing information maps in our minds.

Implied by all this is that it takes time for anyone to build up a large body of well-rounded information. "More is more" has implications for the design of the information bases for interactive learning products, and also for the kinds of interactivity we build into them. What cognitive science has to say about metacognition has implications for how we design browsers and interfaces to operate on the information bases in our products.

Three more findings of cognitive science particularly bear on interactivity and suggest how it may be connected to the kind of user-controlled programs that a place like WNET, with its television broadcasting background, should develop.

1. Visual learning. People find it easier to learn when they are able to represent knowledge to themselves in mental images that the mind can "scan" and that serve to pull ideas together. (Hardly a startling idea; the wisdom of the ages states that "one picture is worth a thousand words.") This is especially true when, as they learn, they construct in their minds models or networks of interrrelated knowledge, in accordance with the cognitive principles already discussed.

2. Visual memory. Memory for information represented visually is greater than for verbal information. (There are hints from the exceptional size of our visual cortexes relative to those of other mammals that the ability to organize concepts by spatial relationships, rather than, say, by smell, may be "hard wired" in the human brain. Of course, speech is unique to human beings; maybe information taken in and internally represented in words is less accessible because speech takes place over time, and we cannot keep many words in mind simultaneously as we can the parts of a visual image.) This encourages us to use visual representation of abstract (hence difficult to learn) concepts and their interrelationships, even when the visual analogies we use are inexact and have to be "debugged" at a later date.

3. Active engagement Deep, long-term understanding requires active, prolonged engagement and construction of meaning. Passive engagement may allow for short-term memory; long-term memory is most effectively developed by a learner's actively reaching out for and manipulating information.

These cognitive propositions seem almost to have been formulated to justify the kind of interactivity that can be achieved on advanced graphics-oriented computers (combined with videodisc technology, in our case), perhaps especially by producers of inherently visual programming, such as those who have had experience with television. In the next section, I will describe some of the ways in which we have tried to bring theory to life and practicality in our demonstration project, "Beyond Einstein."

Beyond Theory: "Beyond Einstein"

The core team to work on "Beyond Einstein" was very small. It consisted of myself as director and Hugh Osborn as associate director and media integrator, Lauren Resnick and Alan Lesgold (both from the Learning Research and Development Center at the University of Pittsburgh) as cognitive scientists and participants in the design process, Neil Patterson as science editor, Gary Zamchick as art director, and Christopher Pino as programmer. Geoffrey Haines-Stiles served as advisor and provided a television series treatment based on a content outline drawn up for us by Paul Davies, the eminent English physicist and writer. Finally, Steven Weinberg (Nobel laureate in physics) and Abraham Pais gave us counsel on the science.

Before going further, I must say that in the end it was Hugh and I who determined the contents and shape of the program. The others named above can only be held responsible for what is right with it, not for its errors in either science or psychology.

In planning for the WNET Learning Lab, we established several criteria—even before the "Beyond Einstein" team came on board—for what would be appropriate subject matter for the first few research and development projects. It would have to be important socially, intellectually, and educationally, and it would have to be difficult to understand and learn.

Why set the barriers so high? This was to be a research activity. We wouldn't be able to learn much if we set the barriers so low that we could clear them on blind luck. If our approach was right, it would do a better job in giving motivated adults access to really challenging intellectual content than past methods had.

How did we decide on quantum mechanics as the subject? It had everything: To put it simply, quantum mechanics says that all physical reality consists of subatomic particles of various kinds that operate on one another through forces conveyed by yet more particles; that individually all these particles behave in random and unpredictable ways; and that there are strict limits to the amount of information we could have about them at any given time, even if we had perfect measuring instruments, because when we observe them, we change them.

Quantum mechanics is central to the rest of the twentieth-century hard sciences: our most characteristic late-century technologies depend on it; it raises really shocking philosophical questions; and it has the romance of being the rock on which one of its principal architects, Einstein, ran aground.

"The Creation of the Universe" is not primarily about quantum mechanics, but about a related topic: the "Big Bang" at the beginning of time. However, the show was wide-ranging, and it contained enough material on the history and concepts of quantum mechanics that, for a demonstration at least, we could reedit large portions of it and supplement them with new material and an information architecture (more on this in a moment) that would allow us to show and test our idea of interactive media.

How to get this material across to nonscientists? The challenge is twofold: technical and psychological. Very often in the past, the technical problems and solutions have driven design, so that learners had to make do with well-engineered but basically opaque programs. We wanted to try it the other way around—to think out what an intelligent, motivated, uninformed adult might want to know and how he or she might be able to come to terms with the subject matter, and then to "reverse engineer" a program to meet these needs.

Following the cognitive principles outlined above, "Beyond Einstein" would have to intrigue learners enough to give them the motivation to start and to go on; somehow it would have to suggest what the contents were without overwhelming absolute novices, and to show how they could find hooks into what they already knew. It would have to provide a means of orienting them to the most important ways of looking at the subject. At all times, would have to give hints about good questions the learner could work on next and how to find the information to answer them. It would have to be entertaining rather than didactic, and it would have to help users make appropriate "schemas" and "maps," just as experts do, to support their understanding and memory. Since the program was going to be interactive, it had to stay fascinating and helpful through many reuses, which meant that it would have to be adaptable to different users' level of knowledge about the subject. It also needed to take into account the fact that the individual users would learn from it, and hence, want increasingly sophisticated information from it as they went along. Holy Toledo!

Sensible people might have quit right there. Instead, the design team members bashed their heads against the issues for quite a long time. We made a lot of false starts that led us back to conventional learning software that seemed all right for school settings where students have to use it, but all wrong for adults who can choose how to invest their leisure and hobby time. "What happened to the *weirdness* of this stuff? Why would people want to interact with a simulation like this?" Gradually, we made progress.

Everyone eventually agreed that there are certain ways of looking at any fact in science that the whole world would find familiar and helpful:

- The science itself—facts about the physical world, the names and actions of the various particles, models of how they work (such as the conventional model of the atom), and so forth.
- The scientists, and the labs and apparatus they used for experiments.

- The issues the science raises, such as "Does God play dice?" and "If the atom is too small to see, how can we learn if there's anything inside it?"

- The applications and uses of science, such as the television tube or the computer, or the nuclear weapon and nuclear power.

In addition, there is another organizing principle everyone uses and understands: time. Time enables us to order things, it helps us ask about whether earlier things caused later ones, and it helps us to ask what else, either in our own histories or in the world at large, happened at the same time, earlier or later.

These five ways of looking at science can all be made to work at once, so that, if we know one fact, we can immediately fill in the rest of the information by asking the right questions and looking efficiently for the answers. In other words, we had devised a *schema* that even a layperson could use for learning quantum mechanics.

An example: Suppose you learn that the electron was the first subatomic particle discovered. Using this schema, you would be in a position to begin looking for answers to other questions in the schematic framework.

When was it discovered? By whom? Where? What kind of apparatus did the discoverer use? How did he or she arrive at that method? Did this discovery raise any important issues about previous scientific knowledge and models? Did it raise philosophical—or even religious—questions? What applications did it lead to? How did those change the way we live? Did the discovery of the electron come before or after the discovery of the quantum? How are the two things connected? (And so on.)

Laying things out this way also supports another basic cognitive principle: that learners need to take an active and questing role in building knowledge, rather than having it packaged for them, however logically.

In practice, our schema told us how to lay out the data base of "Beyond Einstein." This means that, since we were going to encourage learners to pose and answer questions as we've discussed, we had to put the information into the program in the same way.

I should stress here that "information" in this context does not mean only text. It mostly means short pieces of video, audio, and computer data, backed or supported by text only secondarily. The video and audio were to be on videodisc, along with some of the still graphics and facsimile text materials; the rest was to be in a computer software program that would also control the videodisc.

The best way to visualize how we organized the information is to think of a spreadsheet. Along the top, imagine a timeline from 1895 to the present. Down the left-hand side, imagine four headings:

- Physics
- People
- Issues
- Uses

(In practice, we used subheads under each of these in the data base, but that's a detail.) To make the task easier for ourselves and to make sure that all the members of the team were operating from the same model, we festooned my office with butcher paper all around the walls and set up the spreadsheet framework there.

Then we began making 3- by 5-inch file cards; on each one, we wrote a single fact from the history of subatomic physics. Free association helps here. Examples: Nucleus; Rutherford; Cavendish Laboratory; Niels Bohr; Quantum jump; Max Planck; Einstein; Photon.

Take the first card and place it on the spreadsheet. The nucleus is a piece of physics, so it goes in the Physics row. Its discovery was announced in 1911, so it goes under that year in the timeline column. Now Rutherford. He is associated with a number of important advances in atomic physics, but he is credited with the discovery of the atomic nucleus, so he goes in People, directly below Nucleus, at year 1911. Cavendish Laboratory, the lab at Cambridge University where so much of the early work on the structure of the atom was done, was under the direction of Joseph John Thomson when he discovered the electron in 1897, so we can put it with Thomson in the People row (Places is a subhead) below 1897 in the timeline column. That reminds us to put Electron in the Physics line.

And so on. Now imagine that the entire matrix of spreadsheet is filled out, to some arbitrary level of detail. Each item of data (remember, it might be a video clip, a still photo, a piece of voice-over, a page of text) can now be given a unique address in the data base, and we can begin writing a computer program to get at it as appropriate.

There are some interesting technical challenges here, but the most fascinating ones concern what learners would want to be able to do. These boil down to two things: to get some initial orientation to themes in quantum physics through what amount to television shows, and to then move about freely through the information.

The structure of the data base allowed us to create both of these capabilities. If we think of the information spreadsheet as a map, then we can package "tours" simply by specifying which places (data cells) are to be visited in what order. For each such tour, we can create an advance organizer that previews what the tour is about and where it goes. Then we can create a voice-over that ties the individual pieces of media together into a coherent whole. This is what we did for the orientation tours.

We made sure the tours available subtly reinforced the five ways of looking at the science information that we've discussed, since these could be used as learning aids when users began to browse freely through the information map later.

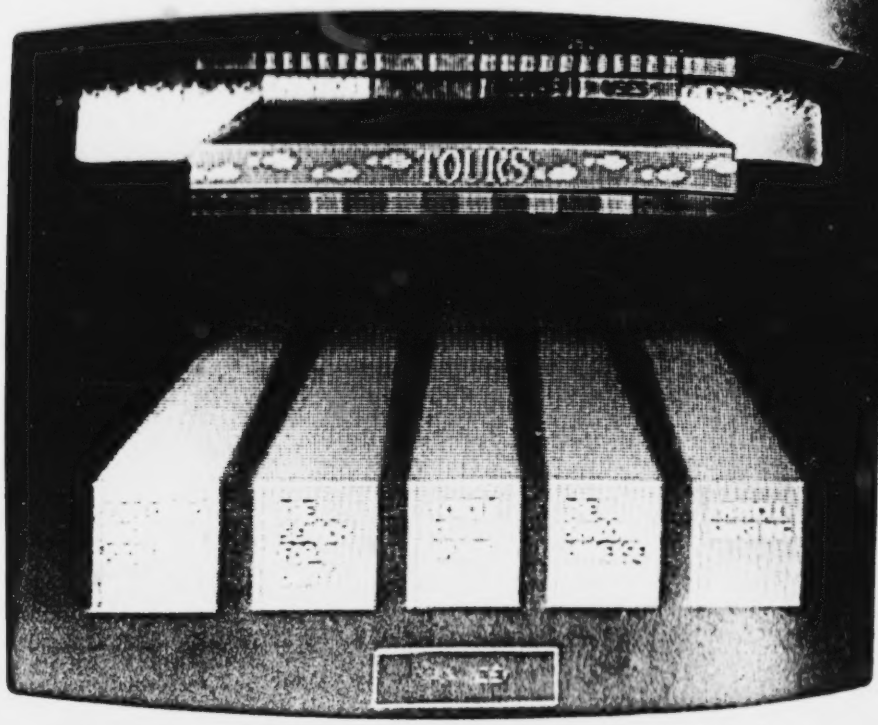
I've already mentioned advance organizers. We decided (it became a joke, in fact, because of the rigor with which it was enforced) that "Beyond Einstein" would not have any menus in the usual sense. We felt that menus are a price users have to pay for getting where they really want to be. However, users have to have some way of finding out what is available and how to get to it, no matter whether it's called a menu or something else. The "choice screens" would have to be entertaining and educational in themselves. Why not make them information maps, with voice-overs to let viewers know what they were looking at and how to use it?

In addition, we could make the maps browsable—that is, merely resting the cursor on a choice for a moment would bring up a voice-over preview of that topic that also, almost subliminally, told how it was related to the other topics on the map. So menus, too, could become real cognitive devices and entertainment in themselves, rather than mere gatekeepers. When the user made a final choice, a simple click of the mouse would take him or her directly to it.

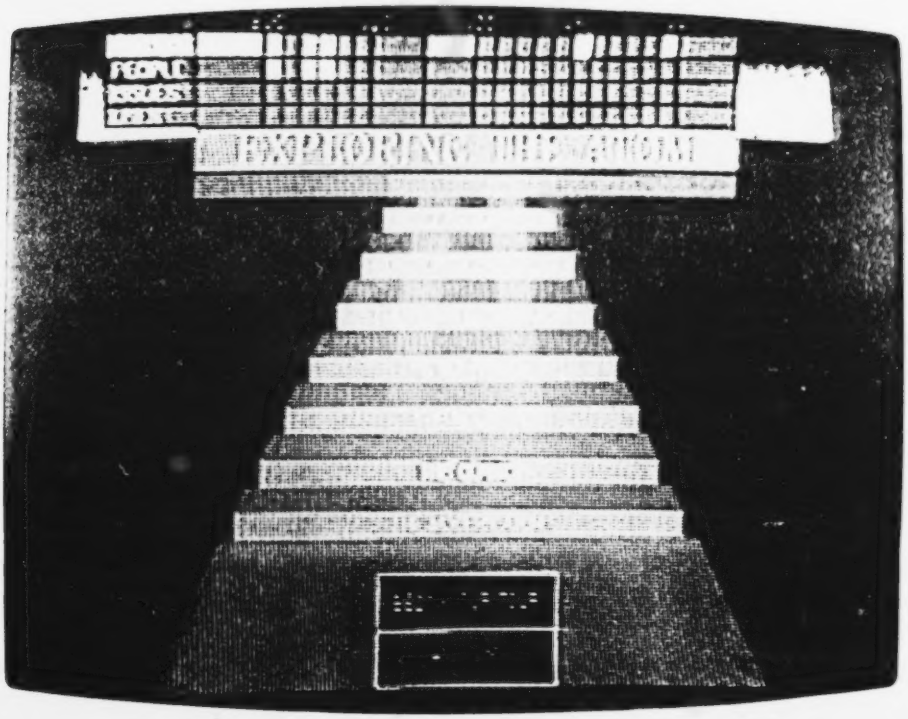
We've looked at the basic information architecture and the way a user gets started in "Beyond Einstein." What happens then? How does one navigate? How does one interact with the system? These two questions turn out to have the same answers in this program. The answers were determined by a combination of the cognitive science that we made a design principle and of a more general concern for what users would want from an informal education product from a source like WNET.

In the end, we defined five kinds of interactivity and navigation in "Beyond Einstein." Most of them are served by more than one feature in the program. I'll list them:

1. Touring. Already mentioned. It serves to orient, suggest ways of looking at the subject matter, motivate, and set people up for later brows



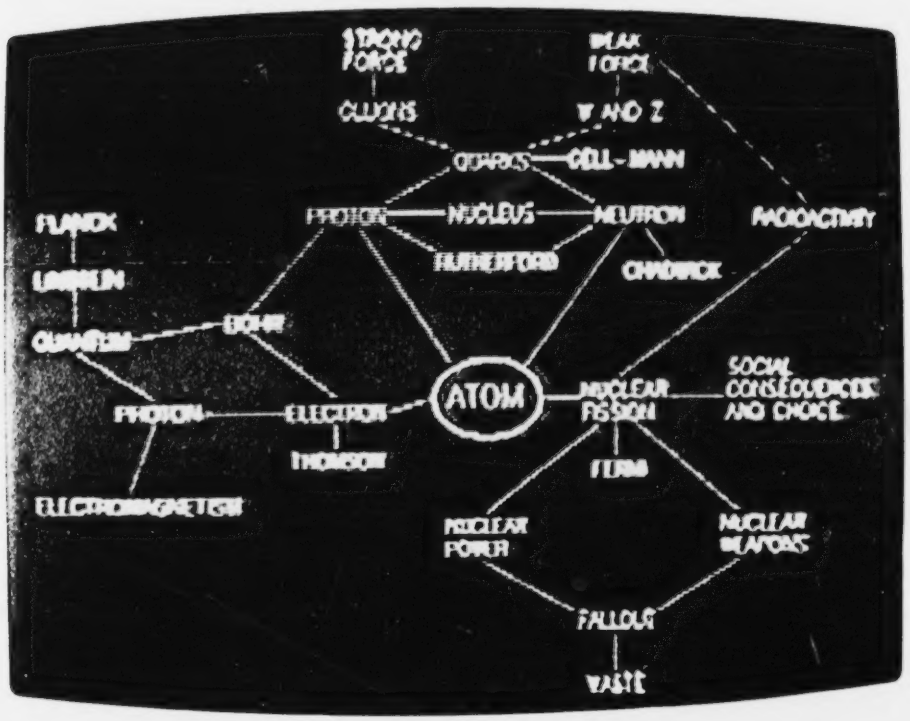
2. Browsing. Also mentioned. When users understand the architecture of the information (the fivefold structure discussed above), they are in a position, especially with the help of the Choice and Topic screens with their advance organizer feature, to begin simply exploring the subject on their own.



3. Connecting. We wanted, everywhere in "Beyond Einstein," to help learners create the kinds of cognitive maps or networks that seem to be so critical for memory and comprehension. The voice-over previews are one example of how we tried to support mapmaking. Another is the feature we called *semantic nets*. (The term derives from work by Quillian and Collins and others on memory.)

Cognitive scientists distinguish between two levels of memory: short-term working, memory, and long-term or semantic, memory. Short-term memory is like a small "buffer" in the mind; we can keep a small number of things in mind for as long as we are working with them. For the longer term, they have to be anchored "semantically" if we are to retain them and be able to recover them at will.

The semantic nets in "Beyond Einstein" occur at the ends of major topic sections. They are patterns of words arrayed around the topic word, color coded as to whether the terms refer to science itself, people or places, issues, or uses of science—in other words, to reinforce and make use of our fivefold schema. They are interconnected by lines that represent precedence, cause, or authorship. They serve as a method of pulling together what was in that section of the program and other material elsewhere in the program, and as a review mechanism. They are also active: clicking on any term in the semantic net takes the user there directly. Thus "connecting" in our sense also means something like "orderly free-associating." Almost every part of the program can be directly addressed from a Choice screen, a Tour screen, or a semantic net.

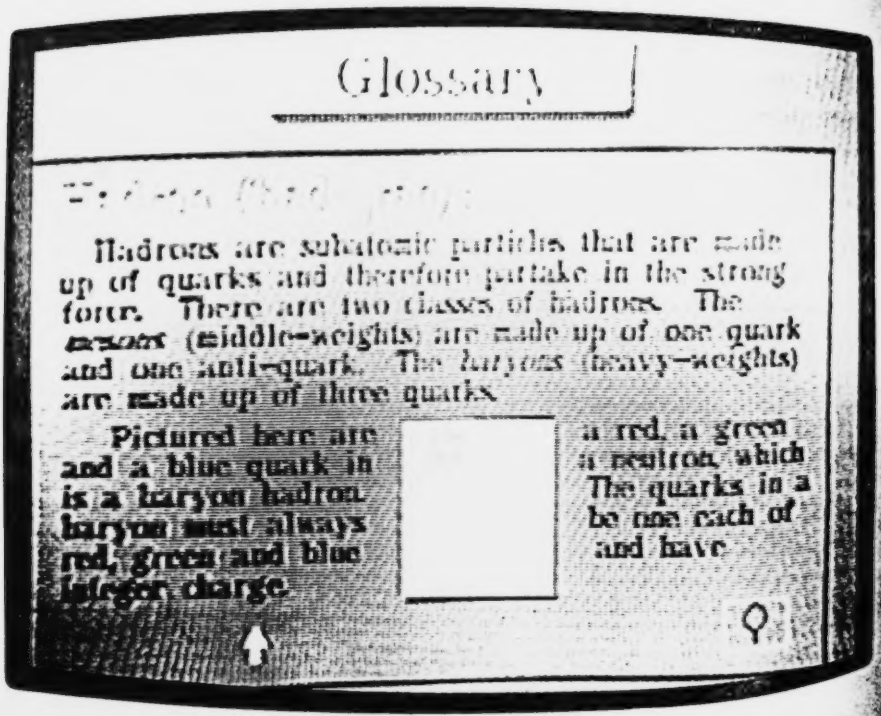

STRONG FORCE
WEAK FORCE
QUARKS
W AND Z
GLUONS
GELL-MANN
PROTON
NUCLEUS
NEUTRON
RADIOACTIVITY
RUTHERFORD
CHADWICK
ATOM
NUCLEAR FISSION
SOCIAL CONSEQUENCES AND CHOICE
PHOTON
ELECTRON
THOMSON
FERMI
NUCLEAR POWER
NUCLEAR WEAPONS
FALLOUT
WASTE

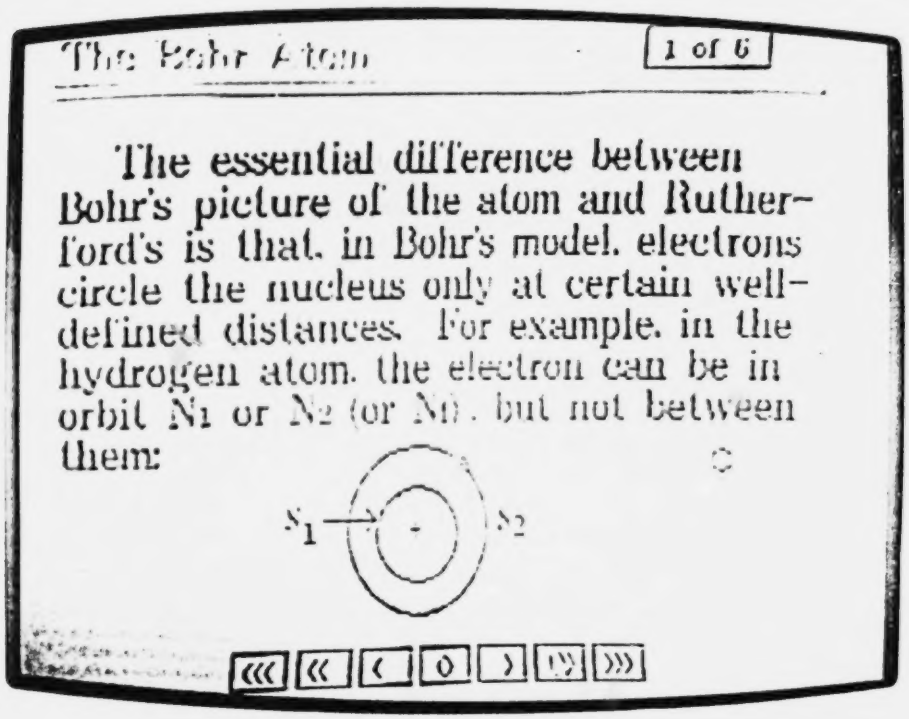
17

4. "Question asking." I started this paper by saying that "The Creation of the Universe" cried out for user control of the pace, and for interactivity. The most obvious kind of interactivity for a program like this is the ability to question it. Being able to stop the show and ask "What was that word again? What did it mean? What did I just see?" would alone transform television into something much more rewarding.

Therefore, we built into "Beyond Einstein" four features to support active questing and adaptivity to individual users. We called them *script, glossary, magnifying glass*, and *motion pause*.

Because the narrative portions of the program inevitably bring up unfamiliar terms that most listeners couldn't even spell, we built in the capability to stop the action and display in text the script of the narrative. In the script, technical terms are highlighted in color. Pointing to one and clicking brings up an entry from the glossary, defining it in multiple media (for example, print and video).


Glossary
Hadrons are subatomic particles that are made up of quarks and therefore partake in the strong force. There are two classes of hadrons. The mesons (middle-weights) are made up of one quark and one anti-quark. The baryons (heavy-weights) are made up of three quarks.
Pictured here are
and a blue quark in
is a baryon hadron.
baryon must always
red, green and blue
(else) for charge.
a red, a green
a neutron, which
The quarks in a
be one each of
and have


The Bohr Atom
1 of 6
The essential difference between Bohr's picture of the atom and Rutherford's is that, in Bohr's model, electrons circle the nucleus only at certain well-defined distances. For example, in the hydrogen atom, the electron can be in orbit N1 or N2 (or N3), but not between them:
N1
N2

The magnifying glass is displayed as an icon at the bottom of the screen whenever (which is often) there are additional levels of information available on the material being treated. Clicking on it first brings up a somewhat expanded version of information, perhaps with a formula written out rather than in mathematical notation, a labeled diagram of experimental apparatus, or a longer selection of text. Going down further would take the user to a level perhaps roughly appropriate for an undergraduate taking a course on the subject. This level might bring up a simulation or the full mathematical representation of the topic.

Finally, the motion pause stops the action and draws boxes around the objects on the screen for which labeling and other information is available. Pointing to a box and clicking brings up a full screen of information, while retaining the box of video in the same position it occupied before the click.

5. "Condition changing." Sometimes the only way to understand what is being said is to set up a model and tinker with it. This we call "condition changing"; it is better known as simulating. "Beyond Einstein" treats simulations as cells of information that can be brought up as appropriate from a variety of different parts of the program. To take one example: the simulation of Niels Bohr's 1913 model of the atom can be reached by taking a tour (on the history of our concepts of the atom), directly from a Choice screen (by clicking "Bohr atom") or from a semantic net; the Bohr atom would appear on several nets. On arrival at the segment on Bohr's concept of the atom and definition of the quantum jump, the simulation would be lying in wait below a magnifying glass. The voice-over would suggest going down to look at it.

If "Beyond Einstein" sounds like a complex design, that's not surprising—it's very complicated. What *is* surprising is that the program is not at all complicated to use. The actual command structure, from the user's point of view, is among the simplest we have ever seen—and deliberately so.

At all times, the screen looks like a television screen, not a computer screen. This is because, in our opinion, most people who are interested in interacting with a program like "Beyond Einstein" have no interest in becoming computer operators. We think they want television to do a better job of helping them learn and remember some of the big subjects. If our program were regarded simply as a more successful form of television or publication, we would be very flattered.

Maximizing Return on Program Investment

One of the unhappiest facts about public broadcasting is that the enormous expense involved in producing high-quality programming brings such a small audience reach for its producers and underwriters. We are not thinking here primarily of financial return (though heaven knows that it's important, too), but of the fact that most programs are seen two or three times, then disappear, taking their investments with them.

By planning interactive products in advance with the producers of related television series, we could not only anticipate reuse of important and expensive video and audio segments, but also plan additional shooting on location, where crews are already needed for the television production. With advance planning, we need add very little to the cost of broadcast programming. We would become producers of interactive material that reuses television programming effectively, because the television was planned with this in mind, and the extra material was produced at low cost, since it involves virtually no new expense in travel and setup.

The skills we develop for making interactive multimedia products—in animation, graphics, and audio, to name a few—have potential future benefit for the broadcast organization as well, especially with stereo and multichannel broadcasting just over the horizon.

Whatever Became of "Beyond Einstein"?

Good question. "Beyond Einstein" is first and foremost a demonstration project. It is finished only on the demo tape. In reality, while there is more on the videodisc than we were able to show on tape, there is less computer programming than is needed for a viable product.

As I said at the beginning, the program is put together from bits of material gathered from several sources. Our plan for an interactive modern physics curriculum for older students and adults, and for a corresponding telecourse, has always been to build from the ground up. The function of the tape is to show what our concept might look like if funded and implemented.

The present demonstration was made on a shoestring. We had a small grant from the Corporation for Public Broadcasting for the development and another from the Hyde-Watson Foundation for equipment. If the core team members had not invested a great deal of "sweat equity" in the project, it could not have been accomplished for the budget. The kind of product that is needed will cost something like $2 million to develop, test, and refine, even with the amount of design already done. WNET is a nonprofit educational television station and production center. Clearly, the funds would have to be raised elsewhere. The question is whether the possibilities demonstrated in "Beyond Einstein" seem worth the investment.

But, as often happens, that is part of the question we need money to answer. Our claim that this program embodies sophisticated ideas of learning, based on the latest cognitive theories, and that it will be more attractive to and effective with older learners than earlier materials, needs a thorough test. The kinds of cognitive outcomes we are suggesting could come from a program like this are very hard to measure. One of the reasons the ongoing research and development of "Beyond Einstein" is worth investing in, in our view, is that it will force an advance in the state of the art of cognitive testing.

In the meantime, "Beyond Einstein" is a set of design principles based on reasoning that can be captured and replicated. This paper does some of that capturing. The replicating is up to all of us.

The need to understand interactive media and develop principled learning products cannot be put off much longer. The time seems to be rapidly approaching when a viable interactive multimedia technology will penetrate consumer and education markets. It may well be based on the compact disc and knit together home audio and video systems. It may, in fact, prove to be the recently announced Compact Disc-Interactive (CD-I). Initially, CD-I will be unable to handle much motion video, and its access times may be slow, but it will be a powerful medium computer based on a very successful audio technology.

The extent to which interactive compact-disc players are overtly computers will be a matter of marketing experimentation on the part of hardware companies, and there may be enough different models to encompass several alternative product concepts: the CD-I player as home entertainment center; CD-I as computer peripheral; CD-I as media computer. We can probably expect CD-I to be around long enough to find its niche in the marketplace.

It is not my purpose to push a technological breakthrough. Whether CD-I succeeds or not, we are so close to the widespread market availability of a machine on which "Beyond Einstein" and its successors will play that it hardly matters exactly what its name will be. What is much more important is *why* it should be, and how we should put it to use in the service of an appropriate goal. The right goal, from the perspective of WNET, is information made transparent and attractive to users. Surely that's something we can all sign up for. "Beyond Einstein" is a start on our exploration of "information transparent and attractive."

Background Reading

For anyone interested in reading further on cognitive science as it might apply to the design of learning materials, I might recommend the following as a one volume introduction:

Cognitive Psychology and Its Implications, by John R. Anderson, published by W.H. Freeman and Company, New York.

Anderson's book was published in 1980, and quite a lot of work has been done since. Nonetheless, it's a fine starting place.

Those feeling the need for strong medicine should begin by reading...

Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness, by P.H. Johnson-Laird, Harvard University Press, Cambridge, Mass.,1983.

For almost the whole world of cognitive science, go on to the catalogs of the Harvard Cognitive Science Series (of which Johnson-Laird's book is one) and the publications of Lawrence Erlbaum, Hillsdale, N.J. Erlbaum makes a speciality of publishing current work by the best-known cognitive scientists. Then follow the citations in the bibliographies of these books.

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Thomas G. Anderson is a Principal with the Boston consulting firm of Commonwealth Strategies, Inc. He has specialized in the fields of publishing and broadcasting, particularly as they deal with education. He has worked since early 1984 with WNET in New York on strategies for interactive media and in developing the prototype "Beyond Einstein."

Earlier, Anderson was the Vice President for Business Planning and Development at Ginn and Company, then part of the Xerox Publishing Group. He was also General Manager of Ginn Press, and of Ginn Electronic Products. In addition, he managed the Technical Seeding Program, which transferred technology from Xerox Palo Alto Research Center to Ginn. He worked with John Seely Brown and others to develop advanced interactive learning materials and to investigate the possibility of transforming the publishing process through the application of new computing capabilities and expert systems.

Before joining Xerox, Tom Anderson was Editorial Director and head of language arts curriculum at Open Court Publishing Company. He was educated at Canadian schools and colleges in the days before cognitive science was born, and had to settle for Classics and English.